

THE EFFECTS OF MOUTH GUARDS AND CLENCHING ON STRENGTH AND POWER  
MEASURES OF A COUNTERMOVEMENT VERTICAL JUMP:  
A PILOT STUDY

by  
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## ABSTRACT

HANNAH HUDSON: The Effects of Mouth Guards and Clenching on Strength and Power Measures of a Countermovement Vertical Jump: A Pilot Study  
(Under the Direction of Dr. John Garner)

Strength and power gains from either mouth guards or clenching have been reported in highly trained athletes from a number of studies utilizing different testing measures. However, there have not been statistically significant effects in a recreationally trained population; and there has not been a research design to combine multiple mouthpiece conditions (mouthpiece designed for performance, a traditional mouth guard, and no mouthpiece condition) with a clench and no clench sub-condition. Therefore, the purpose of this study was to evaluate potential ergogenic effects of mouth guards and clenching on strength and power measures of a countermovement vertical jump. Three recreationally trained males (age  $26.7 \pm 2.9$  years, mass  $89.2 \pm 10.8$  kilograms, and height  $182.0 \pm 2.9$  centimeters) volunteered to participate in three testing sessions, one session for each condition, each separated by one week. The three conditions consisted of a traditional, boil-and-bite mouth guard (MP), a mouthpiece designed for performance (PMP), and no mouthpiece (NoMP). The order of conditions was randomly assigned to participants, and each condition consisted of both a maximal clench and no clench sub-condition, allowing each participant to serve as his own control. Each testing session consisted of a warm up followed by a countermovement vertical jump test performed from a force platform (to gather dependent variables: peak vertical force, normalized peak force, and rate of force development) using a Vertec to measure the final dependent variable: vertical jump height. There were no statistically significant differences ( $p > .05$ ) between conditions for peak force, normalized peak force, or rate of force development. Significant differences in vertical

jump height ( $p < .05$ ) were observed for overall main effect of mouthpiece type and interaction; however post hoc analysis revealed that there were no significant differences between individual conditions. There were no negative effects of either mouthpiece condition when compared to no mouthpiece nor were there for clenching when compared to no clenching. Therefore, this study cannot recommend traditional boil-and-bite mouth guards or performance designed mouthpieces to positively affect strength and power. Likewise, clenching cannot be recommended because further research is necessary with a larger number of participants to come to further conclusions.

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## CHAPTER I

### INTRODUCTION

Using mouth guards as protection is not a new idea. As early as 1915 in the sport of boxing, athletes wore mouth guards for the protection of jaw and teeth. This was based on a 50% chance for dental trauma in boxers (Heintz, 1968). Based on this success, beginning in the early 1960s, team dentist for the Notre Dame football program utilized a combination of off-field jaw alignment correcting splints paired with maxillary mouth guards during practice and games to prevent injuries to teeth, jaw, head, and neck, as well as supporting structures in players with improper jaw alignment (Stenger, Lawson, Wright, & Ricketts, 1964). Players reported alleviation of injuries almost immediately, and they felt they could hit harder when wearing a mouth guard. In 1973, The National Collegiate Athletics Association (NCAA) mandated the use of mouth guards for player protection in the sport of football (NCAA, 2014). Today the mouth guard requirement has been extended to include the sports of field hockey, ice hockey, lacrosse, and others.

In the 1970s and 1980s, lower injury occurrences and strength gains in professional athletes, even those without temporomandibular alignment issues, were reported (Kaufman, 1980; Smith, 1978). Much of this research was reviewed and criticized for improper design and the potential for placebo effects, and critics gave instructions for future research to be carried out in laboratories, rather than by dental clinicians not trained for research.

Research has reported positive improvements in physiological measures, including breathing capacity, lactate production levels,  $\text{VCO}_2$ , and oxygen measures (Francis & Brasher, 1991; Garner & McDivitt, 1995; Garner and McDivitt, 2011a; Mann, Burnett, Cornell, &



Ludlow, 2002; Mueller, Petty, & Filley, 1970). There have been positive reports in measures of strength, power, and anaerobic fitness variables (Arent, McKenna, & Golem, 2010; Cetin, Kececi, Erdogan, & Baydar, 2009; Dunn-Lewis et al., 2012; Forgione, Mehta, McQuade, & Westcot, 1991; Garner, Dudgeon, & McDivitt, 2011a). However, conflicting results have reported a lack of significant findings in physiological measures (Bourdin, Brunet-Patru, Hager, Lacour, & Moyon, 2006) and strength and power measures (Allen, Dabbs, Zachary, and Garner, 2014).

Aside from the contradiction upon whether or not performance increases occur due to mouthpiece wearing is a debate about the mechanisms by which reported improvements have occurred. One on side, researchers have attributed differences to a proper position of jaw alignment that can lead to maximum performance potential, with mouth guards providing the means for this alignment (Fonder, Alter, Allemand, & Monks, 1965; Arent, McKenna, & Golem, 2010; Bourdin, Brunet-Patru, Hager, Lacour, & Moyon, 2006; Forgione, Mehta, McQuade, and Westcot, 1991).

Researchers on the opposing side do not disregard alignment as a possible mechanism, but, instead, cite clenching of the jaw as means by which performance benefits have been reported. Explanations of this possibility exist in many previous studies on mastication (chewing) and its effects on neural activity that can translate to the muscles (Hiroshi, 2003) as well as in research by Ebben, Flanagan, and Jensen (2008) explaining clenching's effects through a phenomenon known as concurrent activation potentiation (CAP) (Ebben, 2006). Garner, Dudgeon, and McDivitt (2011a) cite clenching as normal. Because of that, Dunn-Lewis et al. (2012) instructed participants in their study to do what came naturally in regards to clenching or not clenching on a mouth guard, ultimately suggesting that "a mouth guard that

optimizes jaw positioning when teeth are clenched may optimize power production and rate of force production” (Dunn-Lewis et al., 2012). Allen et al. (2014) did not report significant findings between a mouthpiece or no mouthpiece condition; but they explain that the mechanism may actually be a combination of both jaw alignment and clenching, urging future researchers to utilize a control for clenching in research design to differentiate between explained mechanisms in hopes of bringing opposing sides of this main division together.

Furthermore, a number of previous studies have reported significant increases in strength and power measures when a mouthpiece is worn; however there have not been positive findings in a recreationally trained population. Research has yet to include both a traditional, boil-and-bite guard and a mouthpiece designed to enhance performance with a no mouthpiece condition and maximal clench and no clench sub-conditions. Therefore, impacts of mouthpieces and clenching, both separately and combined, on strength and power variable measures will be the main focus of this paper. The purpose of this study was to evaluate and compare measures of power and strength in a clench and non-clench sub condition with one of three mouthpiece conditions in recreationally trained men: performance mouthpiece for the lower mandible designed by Under Armour (PMP), a commercially available, upper jaw, traditional boil-and-bite mouth guard designed by Cramer (MP), and no mouthpiece (NoMP).

### Hypotheses:

#### **Peak Vertical Force**

H<sub>01</sub>: There will be no statistically significant differences between conditions in highest vertical force measured from the force platform.

H<sub>A1</sub>: Peak vertical force differences between conditions measured from the force platform will be statistically significant.

Ebben, Flanagan, & Jensen (2008) tested countermovement vertical jump and found statistically significant benefits of clenching with a mouthpiece in both time to peak force and rate of force development. Allen et al. (2014) saw some increases, though insignificant, in peak force when evaluating a recreationally trained population, but he did not include the control for clenching as included in our sub-condition. Based upon these findings, this study expects to reject the null hypothesis for peak force because force data collected may result in statistically significant differences between conditions favor the clenching sub-condition.

### **Normalized Peak Force**

H<sub>02</sub>: There will be no statistically significant differences between normalized peak force values when peak vertical force is divided by participant body weight.

H<sub>A2</sub>: Differences between conditions in calculated normalized peak force will be statistically significant.

As above, this study expects to reject the null hypothesis for normalized peak force contingent upon the null hypothesis rejection for peak force, due to normalized peak force's derivation from the same force platform data with its calculation as peak force divided by participant body weight.

### **Rate of Force Development**

H<sub>03</sub>: Statistically significant differences between conditions will not result when rate of force development is calculated from force platform data.

H<sub>A3</sub>: Differences between rate of force development calculations between conditions will be statistically significant.

Previous findings testing rate of force development during a countermovement vertical jump reported that clenching on a mouth guard resulted in statistically significant improvements in rate of force development, with concurrent activation potentiation (CAP) providing the explanation for this resulting increase (Ebben et al., 2008). Based upon the 2008 study and Ebben's (2006) review of the mechanisms underlying CAP, this study expects to reject the null hypothesis for rate of force development because force data collected and used to calculate rate of force development may favor the clenching sub-condition

### **Vertical Jump Height**

H<sub>04</sub>: Vertical jump height differences between conditions will not be statistically significant.

H<sub>A4</sub>: Vertical jump height differences will be statistically significant when comparing conditions.

Two previous studies did find positive effects of mouthpieces on vertical jump measures; however, their populations were current or previous collegiate or professional athletes (Arent, McKenna, and Golem, 2010; Dunn-Lewis et al. 2012). With the population of recreationally trained athletes in the present study, there is likely to be a lack of familiarity with countermovement vertical jump resulting in inconsistency in movement. Based on this research combined with the lack of precise measures in vertical jump height, this study's results expect to fail to reject the null hypothesis directly above.

### Definitions:

**Concentric Force Production:** begins when body mass measured by the force plate is exceeded by the vertical force component of the ground reaction forces curve (Rodgers & Cavanagh, 1984)

**Concurrent Activation Potentiation (CAP):** idea that there is a performance benefit or enhancement when muscles are active concurrently, but away from, the prime mover action (Ebben, 2006)

**Concussion:** any loss of consciousness experienced by a player during contact, whether a momentary loss of consciousness or an amnesia-type disorder that lingers for hours (Stenger, Lawson, Wright, & Ricketts, 1964)

**Hoffman Reflex (H Reflex):** sensory fibers are activated in nerves of muscles unrelated to original action area and reflex electrical stimulation occurs (Ebben, 2006)

**Mouth guard:** referring to a safety appliance (NCAA, 2014)

**Mouthpiece:** referring to a performance appliance (Garner & McDivitt, 1995)

**Occlusion:** relationship between the upper and lower teeth when an individual bites his teeth together and is determined by their spacing and alignment (Fonder, Alter, Allemand, & Monks, 1965)

**Pursed lip breathing:** pursing one's lips and breathing out deeply (Mueller, Petty, & Filley, 1970) to avoid clenching (Ebben, 2006).

**Rate of Force Development (RFD):** calculated as the slope of the ground reaction force curve relative to the onset of concentric force production over time intervals of 0-100, 0-200, and 0-250 milliseconds (Rodgers & Cavanagh, 1984)

**Normalized Peak Force:** peak vertical force value measured from the force plate divided by participants' body weight, expressed as Newtons/kilogram (Rodgers & Cavanagh, 1984)

## CHAPTER II

### REVIEW OF LITERATURE

Athletes in contact sports began wearing mouth guards as protection from dental injuries in the early to mid 1960s, with use in boxing dating as far back as 1915. The 50% chance risk for dental trauma became a reason for boxers to wear a mouth guard (Heintz, 1968). In 1964, John Stenger, team dentist for the Notre Dame football team, utilized a combination of a posterior occlusal splint off the field paired with a maxillary mouth guard during practice and games in an attempt to alleviate injuries reported by players. Prior to Stenger et al.'s interference, many football players were suffering from dental injuries as well as injuries to the temporomandibular (TMJ) joint, head, neck, and supporting structures. He found that many players lacked proper interocclusal or freeway space within the mouth, and he attributed this to improper alignment of their jaw. The combination of splint and maxillary mouth guard was used to correct occlusion in players as well as provide protection for the neck and head in addition to the teeth (Stenger, Lawson, Wright, & Ricketts, 1964).

With the implementation of these appliances, players reported alleviation of face, head, and jaw injuries, such as concussion, after only a few days of splint wearing, lessening their post-injury return to play time. Teammates of those who had been utilizing Stenger's splint and mouth guard began to request these appliances, resulting in a 1963 team with fewer injuries than ever before and players who reported they felt they could "hit much harder than before" when mouth guards were worn (Stenger, Lawson, Wright, & Ricketts, 1964). Stenger explained that the chances of football-related injuries reduced dramatically by realigning the jaw to transfer force

of contact between athletes to the mouth guard rather than joints of the face and jaw (Stenger, 1977.)

Thus, the popularity of mouth guard wearing grew quickly among players, coaches, and athletic trainers alike; as did the popularity of research by dental professionals to show the effectiveness of mouth guards as protection for more than teeth alone. The NCAA first mandated the wear of mouth guards in football in 1973, and they now require a “properly fitted mouth guard” for protection in the following sports: field hockey, football, ice hockey, and both men’s and women’s lacrosse (NCAA, 2014).

In a second study by Stenger (1977), he focused on players with TMJ issues and fitted them with a splint when confirmed. The success of the cases of these players led Stenger to the idea that his posterior occlusal splint and maxillary mouth guards elicited a jaw position “essential to athletes in contact sports” (p. 9 & 10). Stenger reported that the TMJ issues led to overclosure of the mandible. This over closure can lead to over action of the cervical vertebrae and nerves, which causes over-stimulation of the sympathetic nervous system, affecting the entire body.

Fonder et al. (1965) reported a wide range of symptoms that can result due to malocclusion, and they explained that correction of this condition could affect much of the body beyond the teeth, jaw, head, and neck (Fonder, Alter, Allemand, & Monks, 1965). In non-athletes, these temporomandibular joint problems have a variety of origins but can cause many health issues: scoliosis, neck and back pain, muscle weakness, and many other common health issues affecting all body systems (Fonder, 1977; Kaufman, 1980). Work by Stenger, Fonder, and Kaufman popularized the idea that people could be predisposed to injuries or health symptoms due to their jaw position alone. Stenger explained that with the mandible properly suspended,

corrected by mouth guards in his research, there was proper occlusion and support so that players were protected and less likely to suffer from injury. These findings point back to the holistic approach to dentistry: idea that relieving dental distress could positively affect other body systems (Stenger, 1977; Fonder, 1977). The idea that other body systems could be affected, paired with reports from Notre Dame players of increase in the ability to tackle, led to an idea that muscular strength could be related to the position of the TMJ and occlusion. In the late 70s, research with Philadelphia Eagles found a correlation when proper posture and position of the jaw via a wax bite led to significant increases in isometric deltoid strength measures (Smith, 1978).

Stenger's appliances and player cases paired with Smith's reported strength gains popularized the thought that mouth guards could, in fact, lead to performance increases. Harold Gelb developed a mandibular orthopedic repositioning appliance (MORA) in 1979. This appliance, like Stenger's splint and maxillary mouthguard and Smith's wax bite, placed the jaw in a more functional position (Stenger, 1977; Smith, 1978; Gelb, 1985).

Richard Kaufman fit many athletes, ranging from Olympic luge and bobsled teams to hockey players and track and field athletes, with MORAs; and athletes reported a reduction in headaches as well as a loss of tension in the upper body. Many of these athletes also reported strength and power gains: self-described as their ability to push off harder, throw longer, hit harder, etc. Kaufman claimed that even those without TMJ dysfunction could benefit from the wearing of a MORA (Kaufman, 1980).

With the increasing prevalence of the MORA, critics became concerned that MORAs may not have positive benefits on those without alignment issues, but could potentially cause imbalances. Further criticism emphasized the idea that more research was necessary to validate



claims of performance benefits attributed to more than just placebo effect when a mouth guard was worn. Previous research reported only case reports and anecdotal success without statistical analysis or proper research design, much of which was attributed to nearly all research being done by dental clinicians. These flaws in research design called for a combination of the clinical and scientific approach to research. At this time came the transition from research being done by dental clinicians to that done in human movement or performance laboratories (Moore, 1981; Jakush, 1982; Burkett & Bernstein, 1982).

More well designed research continued to return results throughout the 1980s that mouth guards could not be recommended to provide improvements in performance. One study, in 1981, testing upper body strength measures in a controlled clinical trial on participants without evidence of TMJ dysfunction did not return any significant results in favor of the MORA (Greenburg, Cohen, Springer, Kotwick & Vegso, 1981). Research by McArdle et al. (1984) analyzed participants with malalignment issues in a double blind study with random assignment measuring muscular strength, anaerobic and aerobic power, and reaction time. He, too, found no instances of statistically significant increases due to MORA wearing (McArdle et al., 1984). These two studies, however, also found no placebo effect; thus, past criticisms of negative results due to MORA wearing were dismissed.

A review by Forgione et al. (1991) clarified main problems remaining in mouth guard research and concluded that some strength gains did occur (Smith, 1978; Bates & Atkinson, 1983; Kaufman & Kaufman, 1984). Authors pointed out that not all MORAs in previous research were equivalent, and they were not designed for use on participants with proper occlusion. Reports in strength gains all appeared to be isometric. Therefore, quantifying “strength” gains or improvements without clarification was not appropriate, and research should

continue to test isokinetic and whole body movements, as well as other variables. However, due to statistical analysis and review of previously criticized research, Forgione concluded that enough information existed to “conclude that bite position does affect isometric strength in maloccluded subjects” (Forgione, Mehta, McQuade, & Westcot, 1991). After making the conclusion that mouth guards were, in fact, affecting performance; the research began to shift to questions of how and why the effects were happening. The first evaluation of how or why is to examine studies focusing on physiological measures in participants that did not require correction of malocclusion. Research beginning primarily in the early 1990s focused on measures of gas exchange and hormone levels.

In a study by Francis and Brasher (1991), they analyzed breathing capacity in healthy participants wearing over-the-counter, unfitted mouth guards. The authors found that in heavy exercise, breathing with a mouth guard present lead to increases in volume of air expired and decreases in pulmonary ventilation indicating that less air is needed to receive the amount of oxygen needed by the lungs. This was explained by the possibility that with the unfitted mouth guards at heavy exercise, the participants were unintentionally pursing their lips, and measures such as these were found when using pursed lip breathing (Mueller, Petty, & Filley, 1970). It can be stated that metabolic cost of breathing should be lower with mouth guards during heavy exercise, though at lower intensity exercise, appliances led to breathing interference. This was noted by participants’ reporting a feeling of breathing difficulty with the mouth guards used in the study (Francis & Brasher, 1991). Though Francis & Brasher (1991) and others found positive improvements in physiological measures with mouth guard wearing, Bourdin et al. found no statistically significant differences between two mouth guard conditions and a no-mouth guard condition in measures of physiological parameters: visual reaction time, ventilation at rest,

ventilation and oxygen consumption at maximal and submaximal exercise, and explosive power (Bourdin, Brunet-Patru, Hager, Lacour, & Moyen, 2006).

Research with physiological measures continued and changes were found at chemical levels when a performance-designed mouthpiece was worn to result in proper alignment. In a study by Garner and McDivitt (1995), analyzing effects of performance-designed mouthpieces, they found that performance could be improved with a mouthpiece due to increases in measures of endurance resulting from lower levels of lactate production (Garner & McDivitt, 1995).

In a different study by Garner, Dudgeon, Scheett, and McDivitt (2011b) using the performance-designed mouthpiece, they found that  $\text{VCO}_2$  and oxygen measures improved during steady state exercise. Garner et al. backed up their statistically significant findings with two possible explanations. The first is that, perhaps, with the mouthpiece in place, the mandible is in a position so that airway openings are in ideal positioning. Secondly, with the mouthpiece in place, there is activation of the genioglossus muscle due to the positioning of the tongue and that this muscle activity can improve breathing (Mann, Burnett, Cornell, & Ludlow, 2002). Garner et al. (2011b) explained that in comparison to the over-the-counter unfitted mouth guards used in the study by Francis and Brasher, there was a lack of airway obstruction when wearing the custom-fit performance-designed mouthpiece (Francis & Brasher, 1991; Garner, Dudgeon, Scheett, & McDivitt, 2011b).

Studies designed to report on strength, power, and anaerobic fitness, rather than the physiological measures, have also reported positive effects of mouth guard wearing. Early findings by Smith reported the isometric strength gains that ultimately led Forgione to conclude that mouth guards did have a potentially positive effect (Smith, 1978; Forgione, Mehta, McQuade, & Westcot, 1991). Kaufman explained that his athletes had self-reported

improvements in strength and power, but did not quantify these results with scientific evaluation (Kaufman, 1980). However, Bates and Atkinson found positive results in a well-designed study with MORA wearing on power measures of vertical jump and grip tests (Bates & Atkinson, 1983).

More recent studies analyzing anaerobic capacity as well as strength and power have resulted in positive performance measures. In 2009, Cetin et al. tested taekwondo athletes with and without mouth guard wearing and found significant positive effects on peak power and average power in Wingate anaerobic tests as well as significant increases in isokinetic peak torque in hamstrings (Cetin, Kececi, Erdogan, & Baydar, 2009). Another study, compared a standard, custom-fitted mouth guard to a performance designed mouthpiece, that like the one used by Garner et al. (2011a), made controversial performance enhancement claims. However, authors found significantly better measures for Wingate anaerobic test peak power, average peak and mean power for Wingate intervals, and vertical jump. Both of these studies found no negative impacts of the mouth guard/mouthpiece conditions that provided significant results (Arent, McKenna, & Golem, 2010).

The prevalence of significant findings when wearing a MORA or performance mouthpiece led to more questions as to how, what mechanism, was providing the basis for the benefits reported. Early work made claims that any strength gains or physiological changes measured happened via proper alignment of the jaw, often in correction of pre-existing malocclusion (Stenger, 1977; Smith, 1978; Gelb, 1985; Fonder, 1977). Garner, Dudgeon, & McDivitt (2011a) found significant differences in post-exercise cortisol (stress response) levels: lower average cortisol levels present in a mouthpiece group when compared to a no mouthpiece group in division one football players (Garner, Dudgeon, & McDivitt, 2011a). The findings of

lower cortisol levels support a hypothesis by Hori et al. when they found lower stress response in rats when they bit down on a wooden stick while under stress-induction. (Hori, Yuyama, Tamura, 2004). However, Mueller et al. pointed out that much research, including studies by Garner et al., Cetin et al, and Arent et al. did not include instructions on whether or not to clench on the mouth guard when it was worn (Mueller, Petty, & Filley, 1970).

Even in more recent research, there has been an inconsistency in clenching instructions. Dunn-Lewis et al. saw positive performance results of upper and lower body power exercises in trained college athletes with performance mouthpiece wearing, when compared to a regular boil-and-bite mouth guard and no mouth guard condition. There were no specific instructions on mouthpiece or mouth guard use in this study; however, participants were instructed to do what came naturally in all conditions. Authors pointed out that much potential for performance increase when wearing mouth guards or performance mouthpieces has been shown by research specifically for short-burst, high speed, or anaerobic measures (Dunn-Lewis et al., 2012).

On the other hand, Hiroshi gave instructions during a grip strength assessment on a non-athletic population for jaw clenching before and during testing, and no mouth guard was worn. He found significant increases in rate of force development and force production attributed to clenching alone because his lack of mouth guard ruled out the alignment possibility (Hiroshi, 2003).

In 2008, effects of jaw clenching on measures during the countermovement vertical jump were evaluated, finding enhanced rate of force development and time to peak force when participants clenched on a mouth guard compared to not clenching (Ebben, Flanagan, & Jensen, 2008). Ebben explained through these results and in a 2006 review article that there may be a

second mechanism of action causing potential performance gains: concurrent activation potentiation due to clenching.

Concurrent activation potentiation is an idea that there is a performance benefit or enhancement when muscles are active concurrently, but away from, the prime mover action. The muscle actions, often performed maximally, happening away from the prime mover are called remote voluntary contractions (RVCs). When RVCs occur, they elicit functional synergy. This is when the motor cortex is active in one particular area (that of the RVCs) and that activation affects other areas of the motor cortex. With this functional synergy may also come motor overflow where “involuntary movements accompany production of voluntary movements” (p. 985). Therefore, RVCs result in motor overflow, specifically the activation of the Hoffman reflex (H reflex). In an H reflex, sensory fibers are activated in nerves of muscles unrelated to original action area and reflex electrical stimulation occurs. This H reflex results in the potentiation phenomena. When the two muscle actions occur simultaneously, we describe it as concurrent activation potentiation. CAP is particularly optimized with chewing or clenching of the jaw, and thus clenching has been identified as an effecting promoter of the H reflex, and because Ebben explained that increases in H reflex appear to parallel with increases in strength, this may lead to performance benefits in desired muscle areas (Ebben, 2006).

Like Dunn-Lewis, Allen et al. (2014) did not give instructions on whether to clench or not during a mouthpiece or no mouthpiece condition because Ebben reported clenching during maximal effort muscular activity as being common (Ebben, 2006). Allen et al. investigated recreationally trained college-age males’ performance of a CMVJ and a one repetition maximum bench press. Authors did not find significantly different values for CMVJ or bench press measures between mouthpiece and no mouthpiece conditions. They urged future research to

control for clenching and non-clenching conditions in order to differentiate between jaw alignment or clenching mechanisms and to help determine effectiveness of mouthpieces.

Because there is not clarity in some previous research on instructions whether or not to clench when a no-mouthpiece control is utilized, this study will evaluate whether improvements reported while wearing a mouthpiece are due to alignment attained while wearing one of two mouthpieces, clenching elicited when instructed, or a combination of the two. Therefore, the purpose of this study was to investigate clenching vs. not clenching on a commercially available boil-and-bite, performance, mouthpiece and a traditional, boil-and-bite mouthpiece and the effects on measures of power and strength, specifically, countermovement vertical jump (CMVJ) height, rate of force development, peak force, and normalized peak force in comparison to no mouthpiece use in recreationally trained men.

## CHAPTER III

### METHODS

This pilot study examined the hypothesis that ergogenic differences in performance of a countermovement vertical jump (CMVJ) would present themselves between three testing conditions and the two sub conditions within each. The three testing conditions consisted of a) performance mouthpiece for the lower mandible designed by Under Armour (PMP), b) a commercially available, upper jaw, traditional boil-and-bite mouth guard designed by Cramer (MP), and no mouthpiece or mouth guard (NoMP). Each experimental condition had sub conditions: max clench or no clench. In the max clench sub conditions, participants were instructed to intentionally clench maximally on the mouthpiece or mouth guard or by clenching top teeth to bottom teeth in the NoMP condition. Whereas clenching is considered normal, participants were instructed to breathe through puckered lips during no clench conditions because this has been shown to produce an inability to clench (Ebben, 2006). The testing consisted of four laboratory visits. Visit one served as the familiarization session with explanation of testing protocols, obtaining of informed consent, and distribution of mouthpieces with instructions on how to properly fit. The remaining three visits served as testing sessions. Participants were randomly assigned order of conditions to avoid learning effect.

To standardize each testing session and ensure normality, participants were asked to fill out a 3-day dietary recall prior to the first session and a 24-hour recall prior to sessions two, three, and four. Participants were instructed to get normal amounts of sleep, drink plenty of water the night and hours before each session, maintain normal supplement and caffeine intake and refrain from resistance exercise 48 hours prior to testing.



Figure 1: Performance MouthPiece



### Participants

Recreationally trained males (n=3) who exercise in the fitness center on campus were recruited as participants. All participants must have had at least two months (3 sessions per week) of resistance training, olympic lifting, specifically. All participants were required to be free of temporomandibular joint disorder diagnosis and orthopedic injury at the time of the study. Participants were informed of the study procedures and signed University approved Institutional Review Board consent documents before the research protocol.

Table 1: Anthropometric Measures

<u>Participant Demographics</u>	<u>Mean <math>\pm</math> Standard Deviation</u>
Age (years)	26.7 $\pm$ 2.9
Mass (kg)	89.2 $\pm$ 10.8
Height (cm)	182.0 $\pm$ 2.9

### Experimental Procedures

At the beginning of each of the three testing sessions, participants performed a short sequence dynamic warm up consisting of jogging, walking lunges, high knees, butt kickers, and gait swings. Following the warm up, participants performed a max countermovement vertical jump (CMVJ) on a force platform. With each condition (PMP, MP, or NoMP) both clench and non-clench sub-conditions were performed for the CMVJ with fifteen minutes rest between the two. Four dependent variable measures were obtained and/or calculated: vertical jump height, peak vertical force, normal peak force, and rate of force development. The procedures used for CMVJ are outlined below and are consistent with procedures determined by Semenick (1990).

#### *Countermovement Vertical Jump Assessment Procedures*

For each countermovement vertical jump assessment, participants performed three maximal effort jumps on a force platform and the highest jump height values were recorded. All jump height measurements were gathered using a commercial Vertec® measurement device (Sports Imports, Columbus, Ohio, USA). Before jump tests began, participants were instructed to stand under the Vertec with feet flat, shoulder width apart reaching up with the dominant arm to determine max reach height based on the highest vane reached. This height allowed for adjustment of the Vertec vanes to allow for maximal CMVJ measures. Next, participants were instructed to perform each trial by beginning with arms raised at desired starting position and with feet flat, shoulder width apart. Once in starting position, instructions were to bend the knees slightly, and to swing the arms overhead in a maximal jump tapping the highest vane possible out of the way at the top of the jump. Participants performed three trials for both the max clench and non-clench conditions. Measurements of jump height were taken to the nearest half-inch and the highest of the three trials was recorded and converted to centimeters for analysis.

Figure 2: Countermovement Vertical Jump Procedures



Figure 2: Left image depicts starting position (varies depending upon participant hand/arm placement preference; Right image depicts the countermovement bending of the knees

### *Explanation of Force Plate*

CMVJ trials were performed from a 600mm x 400mm force platform (Bertec Inc., Columbus, Ohio, USA). Peak vertical force ( $F_z$ ), normalized peak force ( $nF_z$ ), and rate of force development (RFD) were identified and calculated from kinetic data recorded during maximal obtained CMVJ height from the force platform at a sampling rate of 1000Hz. Normalized peak force was determined from peak force values divided by the body weight of participants (expressed in Newtons/kg). RFD was calculated as the slope of the ground reaction force curve relative to the onset of concentric force production over time intervals of 0-100, 0-200, and 0-250 milliseconds. Concentric force production begins when body mass measured by the force plate is exceeded by the vertical force component of the ground reaction forces curve.

### Statistical Analysis

The study implemented a within subject control where each subject served as his own control through exposure to all mouthpiece conditions and both clench sub-conditions. A 3x2 repeated measures analysis of variance (ANOVA) was utilized to analyze the four dependent variables. Significant main effects or interactions identified through ANOVA were analyzed through Bonferroni post-hoc to reveal individual differences between conditions or interactions. Mauchly's Test of Sphericity was used to determine significance of within-subject effects. All statistical analyses were obtained with SPSS 21 statistical software, and an alpha level of .05 was set a priori.

## CHAPTER IV

### RESULTS

#### Force Plate Data

##### *Peak Force*

No statistically significant differences were found between conditions for peak force ( $p > .05$ ) based on repeated measures ANOVA.

Figure 3: Peak Force

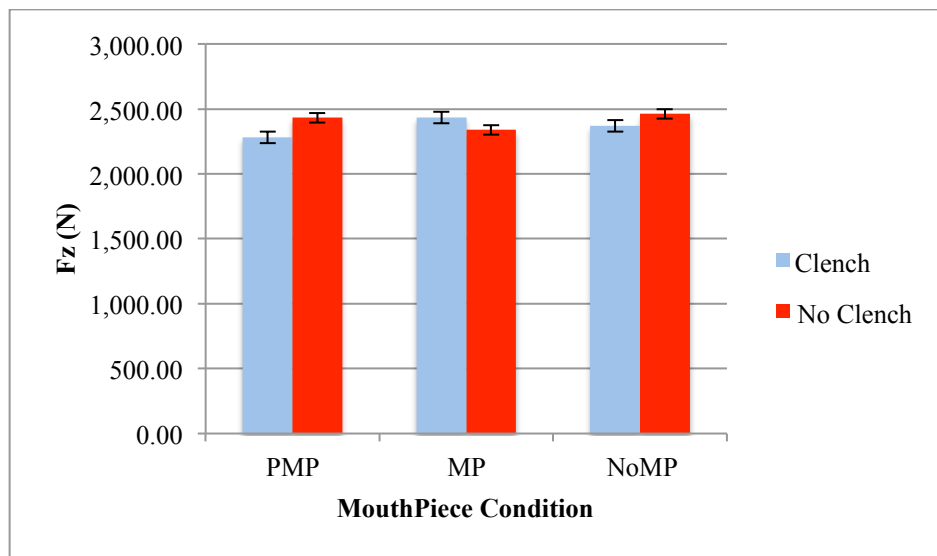


Figure 3: Peak vertical force (Newtons) measured from force platform; no significant differences between mouthpiece conditions or sub-conditions observed

##### *Normalized Peak Force*

Based on repeated measures ANOVA, there were no statistically significant differences in relative peak force ( $p > .05$ ) between conditions.

Figure 4: Normalized Peak Force

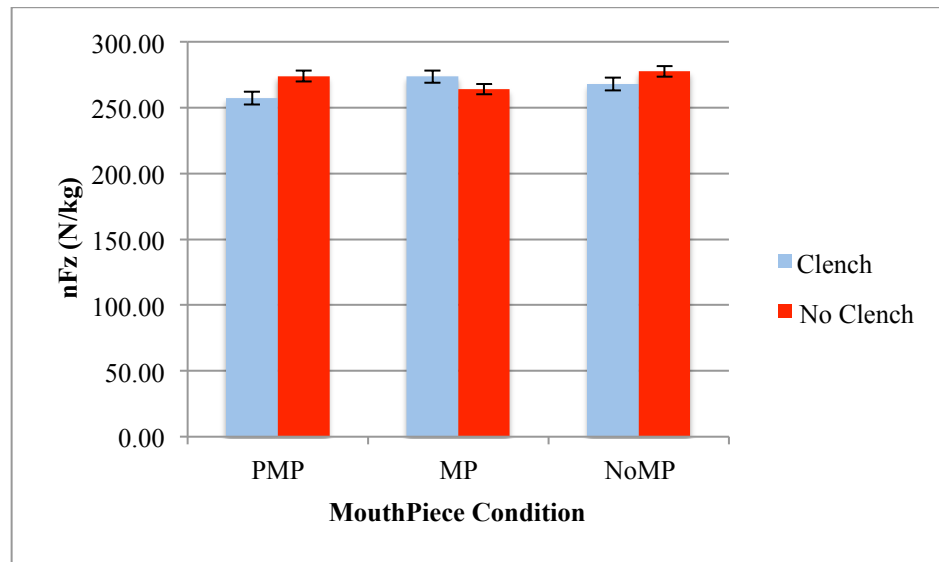


Figure 4: Normalized peak force (Newtons/kilogram) calculated by dividing peak force (Figure 5) by average participant body weight; No significant differences between mouthpiece conditions or sub-conditions observed

#### *Rate of Force Development*

There were no statistically significant differences between conditions for rate of force development values ( $p > .05$ ) found based on repeated measures ANOVA.

Figure 5: Rate of Force Development

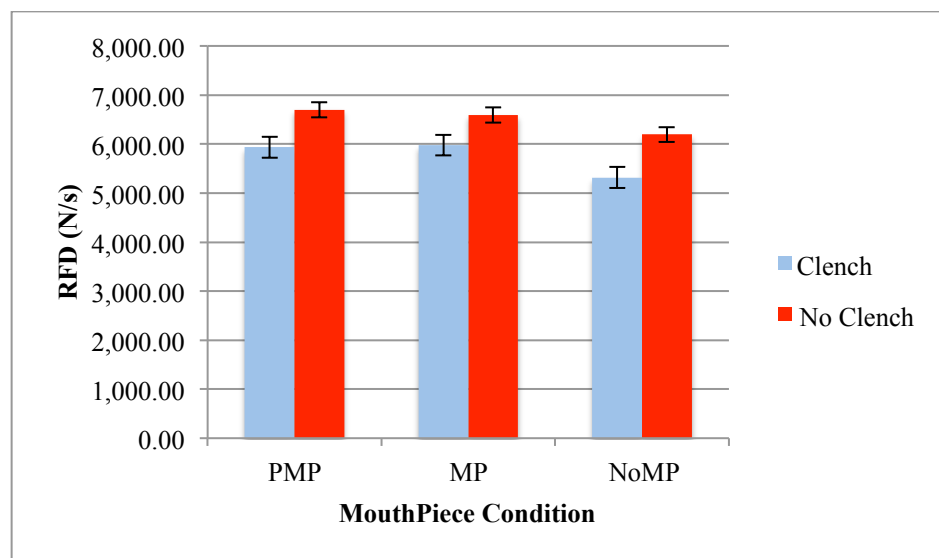


Figure 5: Rate of Force development (Newtons/second) = average over time intervals 0-100, 0-200, 0-250 milliseconds; No significant differences between mouthpiece conditions or sub-conditions observed

### Vertical Jump Height

A 3x2 repeated measures ANOVA was executed to find any differences in the three mouthpiece conditions between clench and no clench sub-conditions. Significance was set at an alpha level of  $p=.05$  and post-hoc comparisons were used to determine condition differences. Mauchly's Test of Sphericity was used to determine significance of within-subject effects.

There were no statistically significant differences between clench and no clench ( $p>.05$ ) based on repeated measures ANOVA. A significant main effect in vertical jump height was found between mouthpiece conditions ( $p=.046$ ,  $R^2=.787$ , power=.626) and as an interaction ( $p=.020$ ,  $R^2=.860$ , power=.832). Bonferroni post-hoc revealed no statistically significant individual differences between mouthpieces conditions ( $p>.05$ ) and no statistically significant individual differences in interaction ( $p>.05$ ) due to differences found via ANOVA being in magnitude but not value (see Figure 7 below).

Table 2: Vertical Jump Height Values

<u>MouthPiece Condition</u>	<u>Maximum Jump Heights</u>	<u>Standard Deviation</u>
PMP (clench)	55.03 cm	6.517
PMP (no clench)	56.73 cm	7.655
MP (clench)	56.73 cm	7.222
MP (no clench)	58.50 cm	8.462
NoMP (clench)	56.73 cm	7.222
NoMP (no clench)	55.88 cm	7.931

Figure 6: Vertical Jump Height - Main Effect\*

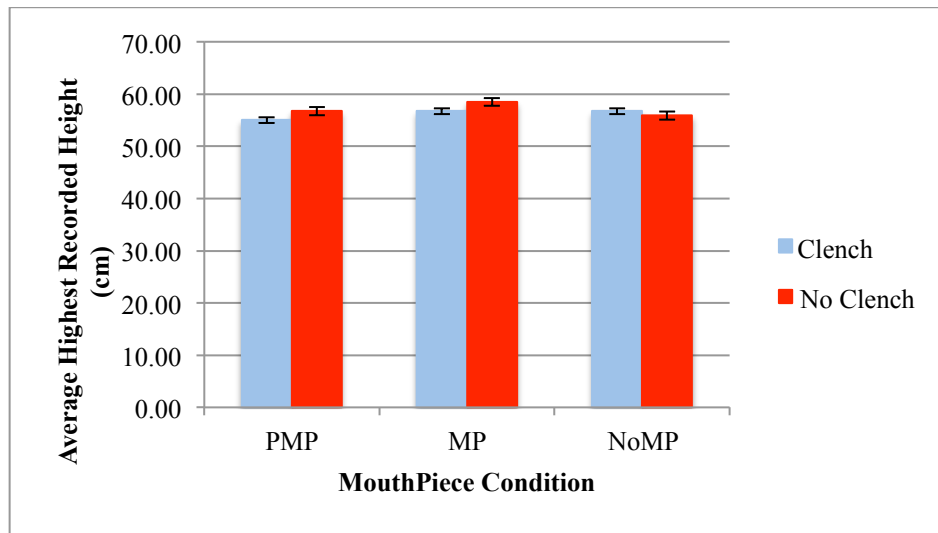


Figure 6: Vertical Jump Height values collected from highest Vertec vanes reached; \*Denotes main effect significant difference

Figure 7: Vertical Jump Height - Interaction\*

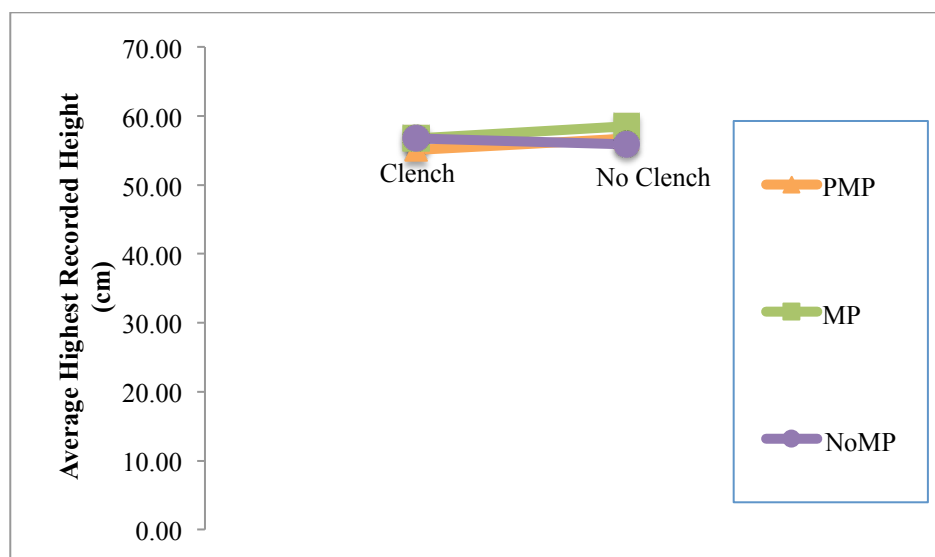


Figure 7: Vertical Jump Height interaction displayed as slope from clench to no clench sub-conditions to display opposite direction of difference in magnitude for NoMP condition; \*Denotes main effect significant difference



## CHAPTER V

### DISCUSSION

This study aimed to evaluate potential ergogenic effects of mouth guards and clenching on strength and power measures of a countermovement vertical jump in recreationally trained males, specifically four dependent variables of vertical jump height, peak force, normalized peak force, and rate of force development. Countermovement vertical jump tests were performed in an acute setting under each of three mouthpiece conditions and clench and no clench sub-conditions. There were no statistically significant differences between three of the four dependent variables: peak force, normalized peak force, and rate of force development. For the fourth variable, vertical jump height, results displayed an overall statistically significant main effect for mouthpiece type conditions and interaction between condition and clench or no clench sub-conditions. However, further analysis via Bonferonni post hoc found no individual significant differences between conditions and the interaction magnitude changes to be insignificant. It is essential to mention that there were no recorded negative effects in variables measured in either of the mouthpiece conditions.

In previous research, Ebben et al. (2008) found statistically significant increases in time to peak force and RFD when clenching on a mouthpiece in comparison to a no mouthpiece, no clench condition in tests of countermovement vertical jump. Furthermore, Hiroshi (2003) observed significant increases in RFD and force production in grip strength when participants' clenched the jaw maximally before and during testing. This study was similar to Ebben et al. (2008) and Hiroshi's (2003) in the instruction for maximal clenching in comparison to no clench as sub-conditions. Our study did, different from these two studies, utilize both a traditional boil-

and-bite mouthpiece and a performance-designed mouthpiece in comparison to a no mouthpiece condition.

Dunn-Lewis et al. (2012) and Arent et al. (2010) both examined countermovement vertical jumps when a jaw-aligning mouthpiece was worn and observed positive performance benefits in the mouthpiece condition when compared to a no mouthpiece condition. Cetin et al. (2009) tested countermovement vertical jump measures with a jaw-aligning mouthpiece as well; however, they found no statistically significant differences between the mouthpiece and no mouthpiece conditions in measures from countermovement vertical jump testing. Dunn-Lewis et al. (2012) gave instructions to perform CMVJs with the mouth and jaw as it felt natural to participants, while it appears that neither Arent et al. (2010) nor Cetin et al. (2009) gave any instructions whether or not to clench during trials; therefore all three lacked a control to quantify clenching as this study did in our comparison of maximal clench to a relaxed jaw position.

It is important to note that all five of these studies utilized highly trained, current or previous college athletes, a population much more trained from the recreationally trained population utilized in this study (Arent et al., 2010; Cetin et al., 2009; Dunn-Lewis et al., 2012; Ebben et al., 2008; Hiroshi, 2003). Allen et al. (2014) found a similar absence of statistically significant strength and power variable measures (specifically peak force, normalized peak force, and rate of force development) in their study utilizing a recreationally trained population, when compared with before mentioned findings with highly trained athletes.

The results in the present do not coincide with hypotheses based on previous findings that statistically significant strength and power differences between conditions would be found, as stated in most of the current literature (Arent et al., 2010; Ebben et al., 2008; Garner et al., 2011a). When observing statistically significant findings in vertical jump height, though found

insignificant when analyzed for individual specific differences via Bonferonni, it is important to note that the measures of vertical height via the Vertec can only be taken to the nearest half-inch. The lack of a more precise measurement makes it very difficult to draw conclusions from significant findings with this measure only. Half-inch height differences may have been seen for a number of reasons outside of ergogenic advantages elicited through a certain condition advantage.

It is imperative to realize that the small participant size ( $n=3$ ) made it difficult to claim any generalizations based on findings. Values used during statistical analysis were the average of only three participants' maximum height or force measurements. The highly trained participants would have been much more familiar with a countermovement vertical jump test. Recreationally trained individuals are often not as used to CMVJ; therefore much variation could be seen from inconsistency in motor recruitment sequence or use of force and speed from the lowest part of the countermovement position to the highest part of the jump (Ghedini Gheller, Dal Pupo, Pereira de Lima, Monteiro de Moura, & dos Santos, 2014; Bracic, Supej, & Matjacic, 2011). With recreationally trained individuals, there is also the possibility that training regimens between the three participants could have differed dramatically. Power lifting type training would result in much different variable measures than slow-and-controlled training, with load weight variability specifically making a difference (Hanson, Leigh, & Mynark, 2007).

#### Limitations and Delimitations

The low number of participants served as a major limitation of this study. It is difficult to draw any conclusions about the effects of the mouthpiece conditions given the limited participant size. Therefore additional subjects would have led to much greater applicability of results to real world strength and power scenarios, and likely variable measures that could better coincide with

findings from previous research. The inclusion of no more than three participants can also be viewed as a delimitation due to this study's identification as a pilot study. The study remained small scale to allow for a small-scale evaluation based upon participant and laboratory space availability within time constraints following IRB review. A major delimitation of this study was the decision not to utilize a population with training greater than recreational level. Because studies utilizing highly trained participants reported significant findings and those with recreational trained participants did not, these results add to the limited availability of findings with a recreationally trained population, which can better translate to the general population than collegiate or professional athletes would.

### Conclusion

This study revealed a statistically significant main effect and interaction in the vertical jump height variable. However, post hoc analysis could not quantify enough statistically significant individual differences found via ANOVA due to their differences being in opposite direction for one condition, but not in statistically significant value. Variables of peak force, normalized peak force, and rate of force development all were found to have no statistically significant differences among conditions or sub-conditions. Therefore, based upon these findings and the small-scale design of this pilot's containing only three participants, these results can not help determine whether performance designed mouthpieces, traditional boil-and-bite mouth guards, or no mouthpiece conditions should be recommended to observe the potential performance benefits found in previous research. The study also did not come to a conclusion as to whether or not clenching resulted in higher performance outcomes. However, it can be concluded, coinciding with previous research, that mouthpieces utilized did not have a negative effect on any of the four dependent variables.

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